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ABSTRACT

This investigation of U.S. and Japanese seventh and eighth grade student achievement in the development of space relations indicated that the Japanese seventh grade mean score was 35% greater than that of the U.S. seventh grade sample and the Japanese eighth grade mean score was 11% greater than that of the U.S. eighth grade sample. Four possible explanations are offered for the differences between the U.S. and Japanese mean space relations scores: (1) development of space relations is a part of the Japanese mathematics curriculum beginning in first grade and not a defined part of the U.S. curriculum; (2) Japanese students have many hands-on activities developing space relations and U.S. students' space relations experiences are principally computation; (3) the Japanese students have the equivalent of 2.4 U.S. school years, or 40% more mathematics experience than U.S. students entering seventh grade; and (4) Japanese students are taught space relations using a Socratic method while U.S. students are taught using a direct instruction method. A further finding is that intrinsic motivation to study mathematics is a significant positive predictor of student development of space relations while extrinsic motivation is a negative predictor. (Author/PK)

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School Mathematics Experiences: A Comparison of U.S. and Japanese Seventh and Eighth Grade Students

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Abstract

The investigation of U.S. and Japan seventh and eighth grade student development of space relations indicates the Japanese seventh grade mean score (35.95) is 35% greater than that of the U.S. seventh grade sample (26.69) and the Japanese eighth grade mean score (36.76) is 11% grater than that of the U.S. eighth grade sample (33.18). The U.S. sample consists of 284 seventh and 265 eighth grade students in a medium sized U.S. school district. The Japan sample consists of 166 seventh and 40 eighth grade students in a school in a medium sized suburban Japanese school. The students were examined when they had completed between 2/3 and 3/4 of their normal school year. Four possible explanations are offered for the differences between the U.S. and Japan mean space relations scores: (1) development of space relations is a part of the Japan mathematics curriculum beginning in first grade and not a defined part of the U.S. curriculum; (2) Japanese students have many hands on activities developing space relations and U.S. student space relations experiences are principally computation; (3) the Japan students have the equivalent of 2.4 U.S. school years, or 40% more mathematics experience than U.S. students entering seventh grade; (4) Japanese students are taught space relations using a Socratic method while U.S. students are taught using a direct instruction method. A further finding is that Intrinsic Motivation to study mathematics is a significant positive predictor of student development of space relations and Extrinsic Motivation is a negative predictor.

Considerable attention is being focused on U.S. elementary and secondary student achievement in mathematics. Comparisons have been made between recent U.S. student mathematics achievement and that of students in schools over twenty years ago (International Association for the Evaluation of Educational Achievement, 1987 [IEA-2]). Additionally, comparisons are being made with U.S. students and students educated in other countries (IEA-2, 1987). The general conclusions are that (1) in most areas of mathematics, recent U.S. eighth grade mean mathematics achievement scores are below that of their U.S. counterparts of twenty years ago and (2) in most areas of mathematics, U.S. eighth grade mean scores are below the median of the means of nineteen other developed and developing countries.

In the 1982 International Association for the Evaluation of Educational Achievement (IEA-2, 1987) study, Japanese eighth grade mean mathematics scores in the five areas tested were the highest of the twenty participating countries. To begin to understand why the achievement differences exist between the U.S. and Japan, an on site investigation was undertaken in both countries.

The present investigation was undertaken to explore similarities and differences in U.S. and Japanese seventh and eighth grade student mathematics experiences. The U.S. data were gathered in the spring of 1984. The students have completed about 3/4 of their school year. The students attend the three middle schools in a medium sized midwest school district. 284 seventh grade and 265 eighth grade students participated. Each grade has three mathematics ability groups. The male-female representation is about equal in each grade and mathematics ability group (Table 1).

Place Table 1 about here

The Japan data were gathered in October, 1984. The students have completed 2/3 of their school year. The students attend a single middle school in a medium sized suburban school district. 166 seventh and 40 eighth grade students participated. The male-female representation is about equal (Table 1). Japanese mathematics classes are not grouped by ability. The curriculum is uniform, prescribed by the State, through grade 9, or the end of compulsory education.

The participants were given Form V of the Psychological Corporation Differential Aptitude Test-Space Relations (Bennett, Seashore & Wesman, 1982), a 60 item test used to measure the ability to mentally construct and rotate a three dimensional figure from a two dimensional pattern. This ability is believed helpful to success in geometry and has strong correlations with student achievement in advanced mathematics, the physical sciences, engineering, and mechanical reasoning (Flanagan et al., 1964).

The Fennema-Sherman Mathematics Attitude Scales (Fennema & Sherman, 1976) were given to measure mathematics related attitudes. This instrument contains nine mathematics attitude scales. The attitudes are measured using a Likert-type scale.

For Japan the instruments were translated into Japanese by a Japanese educator, back into English by a second translator, and reviewed for accuracy by several bilingual Japanese scholars.

In the U.S. and Japan the mathematics classroom teachers administered the instruments during the normal mathematics classroom period.

In addition to the instruments, data was collected from classroom observation, conferences with administrators and teachers, text books and the curriculum guides. Each participating mathematics classroom was observed by this researcher one or more times prior to the testing. Observations were recorded on teaching methods, classroom interaction, and procedures used for evaluating student work or progress.

The data gathered indicates the Japan seventh grade mean space relations score is 35% greater than that of the U.S. seventh grade and the difference is statistically significant (Table 2). The Japan eighth grade mean is 11% greater than the U.S. eighth grade mean (Table 2). The U.S. eighth grade mean is 24% greater than the U.S. seventh grade mean and the difference is statistically significant (at $p < .01$) (Figure 1). The Japanese eighth grade mean is 2% greater than the seventh grade (Figure 1).

It is likely the Japanese space relations are nearly fully developed while those of the U.S. students are not. By U.S. standards, the Japanese seventh and eighth grade space relations means are above the U.S. eighth grade 90th percentile and that of the U.S eighth grade is between the 75th and 80th percentile (Bennett et al., 1982).

Place Table 2 about here

Place Figure 1 about here

The regression analysis of nineteen independent variables on space relations indicates student age has the largest beta weight followed by student

mathematics ability group (Table 3). When separate regression analyses are performed for the seventh and eighth grade, the student mathematics ability group beta weight increases from seventh grade (0.25 at $p < .01$) to eighth grade (0.41 at $p < .01$).

Place Table 3 about here

The standard deviation unit, d, between the highest U.S. mathematics ability group in each grade and the lower ability groups ranges from -.45 to -1.24 (Table 4). If age were in fact the largest predictor of student development of space relations, one would expect the Japan space relations means and percent change from seventh to eighth grade to be similar to those of the U.S (Figure 1). However, this is not the case.

Place Table 4 about here

Several possible explanations are offered for the differences between the U.S. and Japan mean space relations scores and the change in these scores from seventh to eighth grade. One is the early introduction, in preschool, to paper folding activities. 50% of the Japan sample entered 3 day per week preschool at the age of three. In the preschools, as well as in grades 1-6, students fold paper to resemble patterns of birds, flowers, etc. To be successful, great care is taken to reproduce the relationships of lines and angles. It is reasonable to conclude that these experiences may help develop spatial relationships and the ability to visualize geometric figures and vectors in mathematics.

No similar experiences were found for the U.S. students. The non-accelerated U.S. eighth grade general mathematics ability group had no geometry experiences. This ability group's mean space relations score (26.52) (Table 4) is not significantly different from the U.S. seventh grade mean score (26.69) (Table 2).

A second possible explanation for differences in the space relations mean scores between the U.S. and Japan seventh and eighth grades is the difference in the amount of time spent in the study of mathematics in grades one through six. Space relations is a defined part of the Japan mathematics curriculum beginning in grade one (Japan Society of Mathematics Education, 1979). The Japanese students entering seventh grade have the equivalent of 2.4 U.S. school years more mathematics instruction than their U.S. peers (Table 5). This is the equivalent of 40% more school time spent in the study of mathematics. It is likely that the inclusion of the study of space relations in the formal mathematics curriculum and the additional time spent in the study of mathematics contributed to the differences found between the U.S. and Japan mean space relations scores.

Place Table 5 about here

A third possible explanation relates to teaching methodology. In Japan the study of geometric figures begins with developing student spatial understanding of relationships of lines, angles, enclosed figures. The teachers observed used a Socratic method of inquiry to develop student ability to orally describe and compare geometric figures. By seventh grade, students are rather proficient. Sometimes students made errors while developing a

description or comparison. Generally students discovered their own errors. The teachers refrained from correcting student errors in public. To do so would cause the student disgrace and break the harmony of the class. It also is believed to hinder the student's ability to critically analyze the argument he/she is developing.

The U.S. teachers in this sample approached teaching geometric relationships a bit differently. Few classrooms in the U.S. sample were observed or reported using geometric construction and/or analysis of figures as a part of the mathematics program. There was no tradition of students engaging in these activities through the lower grades, as was found in Japan. For most U.S. students, geometry did not appear in the mathematics curriculum until eighth grade and was generally taught as a continuation of computation, measurement and memorization of formuli. Socratic inquiry was seldom used. Direct instruction with the student's single response being either correct or wrong was the common method.

The results of the U.S. regression analysis, described earlier, tend to reinforce the concept that students perform better when the teaching methodology places emphasis on understanding concepts rather than achieving top scores. The beta weight for extrinsic motivation is negative (-0.02) and positive for intrinsic motivation (+0.12 at $p < .05$). Students who perform less well in space relations are more motivated by getting top grades in mathematics and students who perform better are motivated to study mathematics because they enjoy the challenge of understanding and solving mathematics problems. The Japan correlation analyses indicate this relationship even more strongly.

In summary, increasing the amount of time spent studying mathematics and the inclusion of space relations in the school curriculum beginning in first grade are likely to increase student development of space relations. Regular, active participation in the construction of three dimensional figures and in critical analyses of geometric figures seem to have a positive effect on developing space relations. A teaching methodology which includes active student mental participation in developing the structure of a concept appears to increase student achievement. In Japan these approaches to teaching and learning have been observed beginning in preschool and continuing through grade nine.

The comparison of one school in Japan with one district's schools in the U.S. is not an exhaustive comparison. The differences observed were sufficient to merit consideration. The similar significant motivation findings seem to be important to a further understanding of methods to increase student mathematics achievement.

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Table 1

Space Relations Means[a] and S.D. by Grade, Ability Group, Gender and Country.[b]

Group	Female			Male		
	n	mean	S.D.	n	mean	S.D.
			U.S. sample			
Eighth grade	134	33.91	11.91	114	32.44	12.84
(1) Accelerated algebra	29	42.10	9.73	28	41.57	11.10
(2) Middle school algebra	51	36.78	10.49	28	36.11	11.31
(3) General mathematics	54	26.80	10.27	58	26.26	11.02
Seventh grade	131	25.86	9.35	133	27.50	11.47
(4) Accelerated mathematics	53	30.51	9.04	46	34.28	12.56
(5) General mathematics	56	24.09	8.53	63	24.26	9.30
(6) Low mathematics	22	19.18	6.22	24	23.29	9.48
			Japan sample			
Eighth grade	17	33.00	12.26	21	39.81	16.54
Seventh grade	82	35.34	11.35	83	36.54	11.34

Note. No statistically significant gender differences were found with p at .05.

[a]Total possible space relations score is 60.

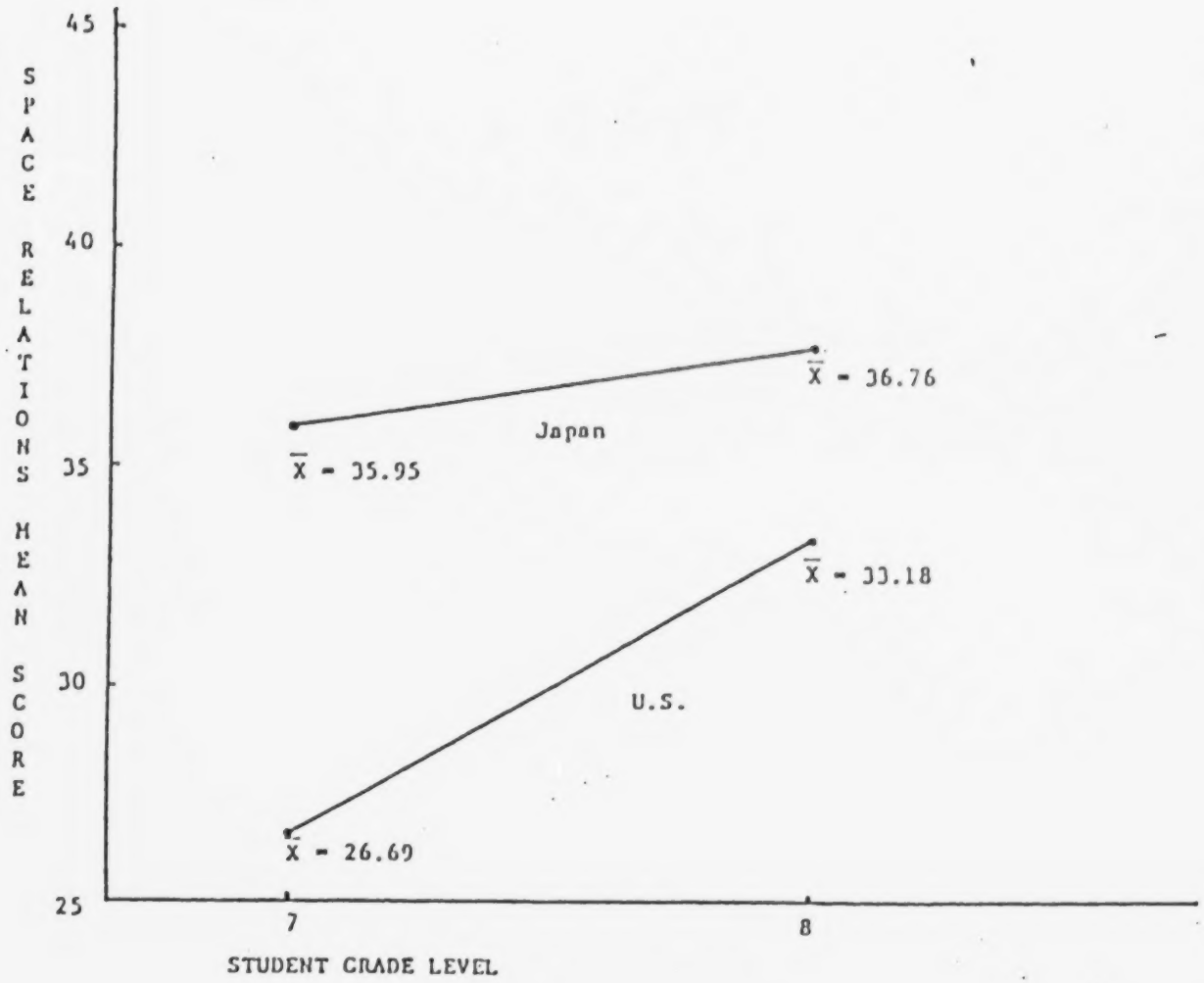
[b]Iben, 1986.

Table 2

U.S. and Japan space relations means[a] and S.D. by grade and % difference between countries.

Grade	United States			Japan			% difference
	n	mean	S.D.	n	mean	S.D.	
8	248	33.18	12.35	38	36.76	14.99	11%
7	264	26.69*	10.48	165	35.95*	11.33	35%

Note. Asterisks designate statistically significant differences between countries at a single grade.
[a]Total possible space relations score is 60.
*p at .01.



Note. Total possible space relations score is 60.

Figure 1. Change in space relations means between grades seven and eight, U.S. and Japan.

Table 3

Space Relations Standardized Beta Weights for Multiple Regression Analysis:

U.S. Sample

	Total sample n=512	Seventh grade n=264	Eighth grade n=248
Student grade level	0.39**		
Math ability group[a]	0.33**	0.25**	0.41**
Interest in math	0.17**	0.20*	
Math intrinsic motivation	0.12*		
Teacher attitude[b]	-0.12*		
Ethnic background[c]	-0.17**	-0.22**	-0.14*

Note. Only beta weights with significance p at .05 or less are reported.
[a]Math ability group is coded eighth grade high school algebra and seventh grade accelerated math, 3; eighth grade middle school algebra and seventh grade general math, 2; and eighth grade general math and seventh grade low math, 1.
[b]The negative beta weight for the teacher attitude indicates that as the student perceives the teacher as more supportive of the student study of mathematics, the student space relations scores decline. It is also a measure of student dependency behavior in mathematics.
[c]Ethnic background is coded Caucasian, 1; Black, 2; and Oriental, 3.
*p < .05. ** p < .01.

Total sample:
Adjusted R^2 = 0.34, R = 0.58
19 and 432 degrees of freedom
F = 13.22**
**p<.01

Seventh grade:
Adjusted R^2 = 0.24, R = 0.49
18 and 219 degrees of freedom
F = 5.09**
**p<.01

Eighth grade:
Adjusted R^2 = 0.30, R = 0.55
18 and 195 degrees of freedom
F = 6.11**
**p<.01

Table 4

Space Relations Means[a], S.D. and d[b] by Mathematics Ability Group: U.S. and Japan Samples

Mathematics Group	United States n	mean	S.D.	d	Japan n	mean	S.D.
Eighth grade					38	36.76_B	14.99
Accelerated algebra	57	41.84_A	10.34				
Middle school algebra	81	36.34_B	10.81	-0.45			
General mathematics	112	26.52_D	10.62	-1.24			
Seventh grade					165	35.95_B	11.33
Accelerated mathematics	99	32.26_C	10.92				
General mathematics	121	24.13_{DE}	8.91	-0.78			
Low mathematics	46	21.33_E	7.69	-1.04			

Note. Means having the same subscript are not significantly different at $p<.01$.

[a]Total possible space relations score is 60.

[b]d is the difference between the means of the most accelerated mathematics group and each of the other two groups in each grade, expressed in standard deviation units.

Table 5

Total Number of School Hours Prescribed for the Study of Mathematics; by Grade and Country

Grade	Hours per year		
	U.S.	Japan	% difference[b]
1	120[a]	136	-13
2	120	175	-46
3	120	175	-46
4	120	175	-46
5	120	175	-46
6	120	175	-46
Total[c]	720	1011	-40
7	150[d]	105	+30
8	150	140	+07
Cumulative Total	1020	1250	-23

[a] Based on 180 forty minute school mathematics periods per year.
[b] A negative sign indicates the number of hours Japanese students spend studying mathematics is greater than that of the U.S. students.
[c] The difference between the U.S. and Japan total number of school hours spent studying mathematics at the end of grade six is equal to 2.4 U.S. school years.
[d] Based on 180 fifty minute school mathematics periods per year.